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SPC Water Resource Center Webinar: Green Infrastructure Implementation Lessons Learned

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Water Resource Center
Southwestern Pennsylvania Commission

*Planning future workshop/webinar topics is currently underway! Please contact Erin Kepple-Adams, Water Resource Manager at **ekepple@spcregion.org** and let her know what your needs are. She is happy to try to accommodate your requests.*

Presentation Outline

- Background
  - What is green infrastructure and why does it matter?
  - Typical challenges / myths
  - Factors impacting implementation / cost
- Lessons Learned on…
  - Planning
  - Design
  - Construction
  - Maintenance
- Resources
- Q&A

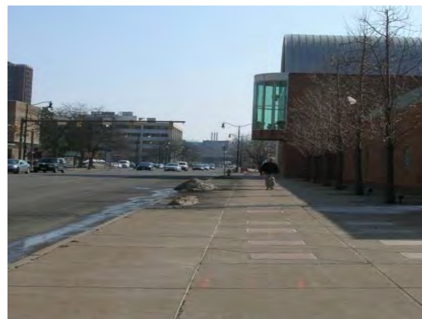
Poll Question #1

What is your organizational affiliation?

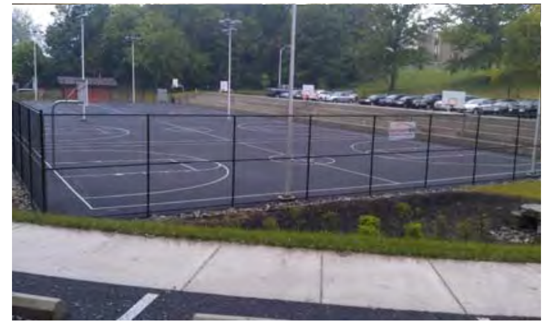
Background

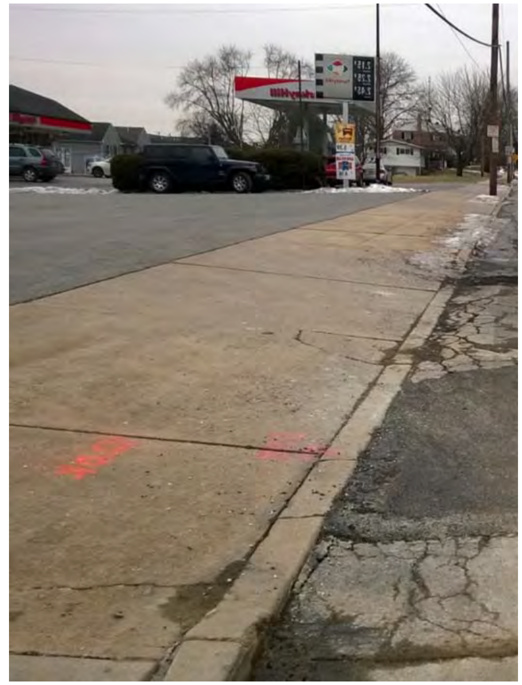
What is green infrastructure and why does it matter?

The World As We Know It



The World Transformed by Green Infrastructure



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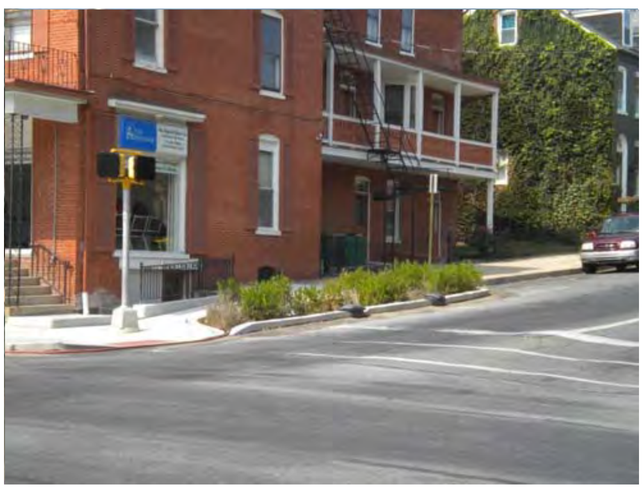


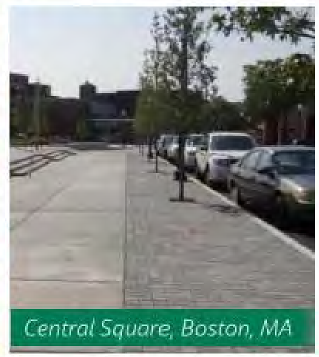
What is Green Infrastructure?

- *An approach to water management using BMPs that preserve or mimic natural processes to* ***infiltrate, evapotranspirate, or reuse stormwater runoff*** *on the site where it is generated*
- Eliminate/train/slowly release runoff for more frequent storm events (i.e. first 1-1.5" rainfall)
- Also known as low impact development, green stormwater infrastructure, natural infrastructure, nature-based infrastructure…


East Liberty Presbyterian Church, Pittsburgh, PA


Rosamond Gifford Zoo, Syracuse, NY


Woodlawn Library, Wilmington, DE


Central Square, Boston, MA


Fulton Street, Lancaster, PA

Brandon Park, Lancaster, PA


Right-of-Way Bioswale, Bronx, NY

Why Does Green Infrastructure Matter?

- Responsive to drivers such as new/re-development stormwater regs, MS4, CSO, green building certifications, etc.
- Primary stormwater benefits: reduced volume, flow rate, and pollutants from stormwater runoff

Many other benefits, including improved:

- Groundwater recharge
- Aesthetics, quality of life
- Resiliency
- Safety / walkability
- Air quality, urban heat island
- Property values
- Localized flooding
- Biodiversity / habitat
- Social value / equity, etc.

Typical Challenges / Myths
(for GI implementation regionally and SW PA particularly)

- Won't work w/ clay soils and steep slopes
- There's not enough space
- There's too much rain / flooding
- Concerned about safety and mosquitos
- Won't last the winter
- Too hard to maintain
- Too many bad past experiences
- Utilities, utilities, and more utilities!
- NIMBY
- It's too expensive!!

Factors Impacting Implementation and Costs

- **Performance criteria** (e.g., capture volume, pollutant removal)
- **New construction vs. redevelopment vs. retrofit**
- **Slope and Soils (permeability, limiting layers, etc.)**
- GI type and implementation mechanism
- Land use
- Site specific location and accessibility constraints
- Demonstration and education goals
- Visibility and importance of aesthetics

Factors Impacting Implementation and Costs

- **Presence, density, and alignments of existing utilities**
- **Level of integration with other capital project needs**
- **Space limitations/proximity to basements/structures**
- Anticipated vehicular and pedestrian traffic
- Local market conditions
- Land value (if acquisition is required)
- Geotechnical considerations

Table 1-2. Planning-Level Estimates of Cost Impacts Associated with Various Relative Constraints to GSI Implementation (cost increases that might be expected compared to a location without that constraint)

Relative Constraints	Potential Cost Implications	Constraint Subcategory	Approximate Cost Increase
Utility Pipe Corridors	Cost of liner and/or protecting/working around utilities	-	18% - 25%
Slopes	Extra excavation/fill, baffles, sheeting and shoring	5 to 9.99%	5% - 7%
		10 to 14.99%	15% - 21%
		15 to 24.99%	25% - 35%
Hydrologic Soil Group (HSG)	Increased excavation costs for urban soils, need for underdrains, soil amendments	B/D	8% - 11%
		C	3% - 4%
		C/D	8% - 11%
		D	10% - 14%
		Urban Fill	5% - 7%
Depth to Bedrock	Shallow bedrock could increase excavation costs and/or liner costs	1.1 to 2.6 feet	15% - 21%
		2.6 to 5.0 feet	5% - 7%
		5.0 to 5.7 feet	3% - 4%
Depth to Water Table (annual minimum)	Shallow water table could increase excavation costs and/or liner costs	Less than 0.49 feet	25% - 35%
		0.5 to 1.35 feet	20% - 28%
		1.36 to 1.9 feet	15% - 21%
		1.91 to 2.26 feet	13% - 18%
		2.27 to 2.59 feet	10% - 14%
FEMA 100-year Floodplains	Cost impact more on the O&M/restoration side	-	15% - 21%
Forest Land Cover	Tree removal/replacement and/or protection	-	13% - 18%
Brownfield Parcels, Parcels with Abandoned Mines, Cemeteries	Cost of liner and/or soil disposal	-	15% - 21%
Streets/Roadway	Increased demo and/or pavement/curb restoration costs	-	8% - 11%

GI Implementation Lessons Learned

Effective planning, design, construction, and O&M can help overcome the many challenges and yield cost-effective projects

Poll Question #2

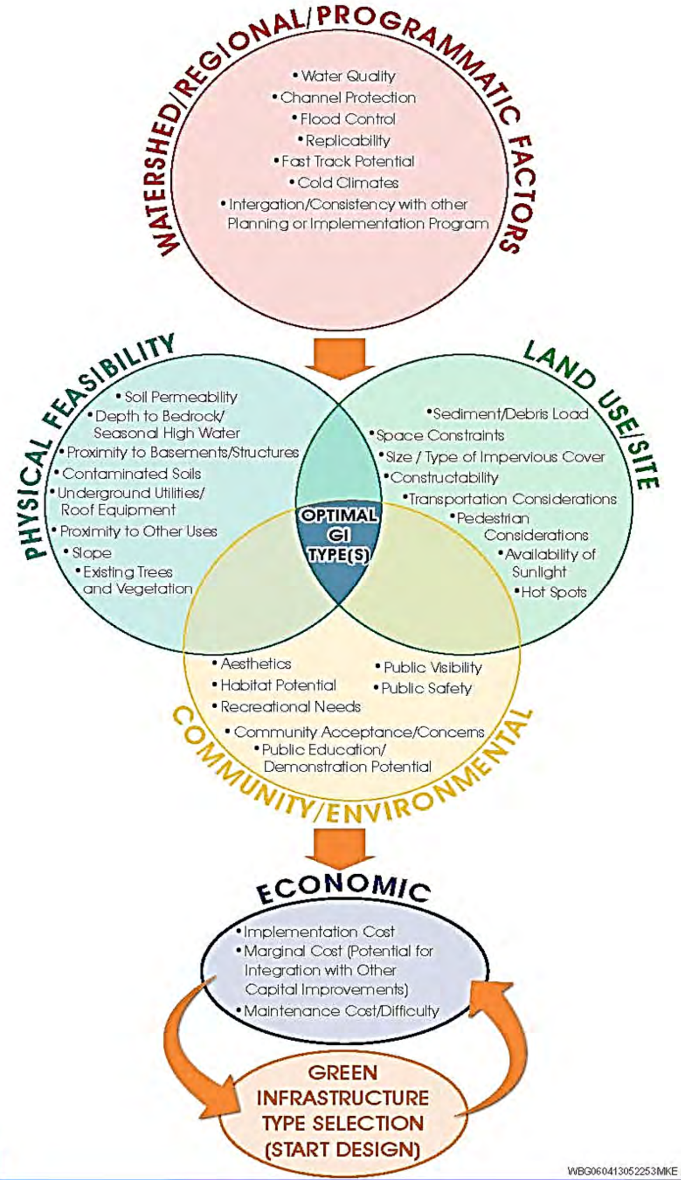
What are the greatest challenges or concerns you have regarding green infrastructure implementation?

Planning

How can planning and conceptual design yield potential green infrastructure projects that are high impact, cost-effective, and community enhancing?

GI implementation planning is not one-size-fits-all. Many factors are considered.

- Watershed/regional/ programmatic
- Physical feasibility
- Land use/site
- Community/environmental
- Economic



Process to Identify and Prioritize Opportunities

Context	Performance & Benefits	Constraints	Opportunities	Concept Plans and Costs	Prioritization
			Public Strategies: Green Streets Municipal / PennDOT; Green Parks; Green Schools and Facilities; GROW Eligible Private Strategies: Redevelopment SW Ordinance; Downspout Disconnection; Coordination with GROW Eligible advocate municipalities		
Understand context for natural and built systems, such as watershed/ sewershed boundaries, land use, population, soils, and sewer infrastructure systems.	Highlight areas where significant overflow reduction can be achieved based on the characteristics of the sewer system.	Analyze constraints including natural characteristics such as shallow bedrock, steep slopes and poor soils for infiltration.	Consider previously identified projects and identify new opportunity areas by analyzing parcel ownership and land use with relatively low constraints; situated in areas where significant overflow reduction can be achieved.	Develop site-specific concept plans and cost estimates, considering integrated costs versus standalone project costs.	Evaluate and prioritize opportunities based on cost and anticipated overflow reduction.

Constraints Analysis – Watershed/Neighborhood or Site Scale

Infrastructure-Based Constraint Analysis

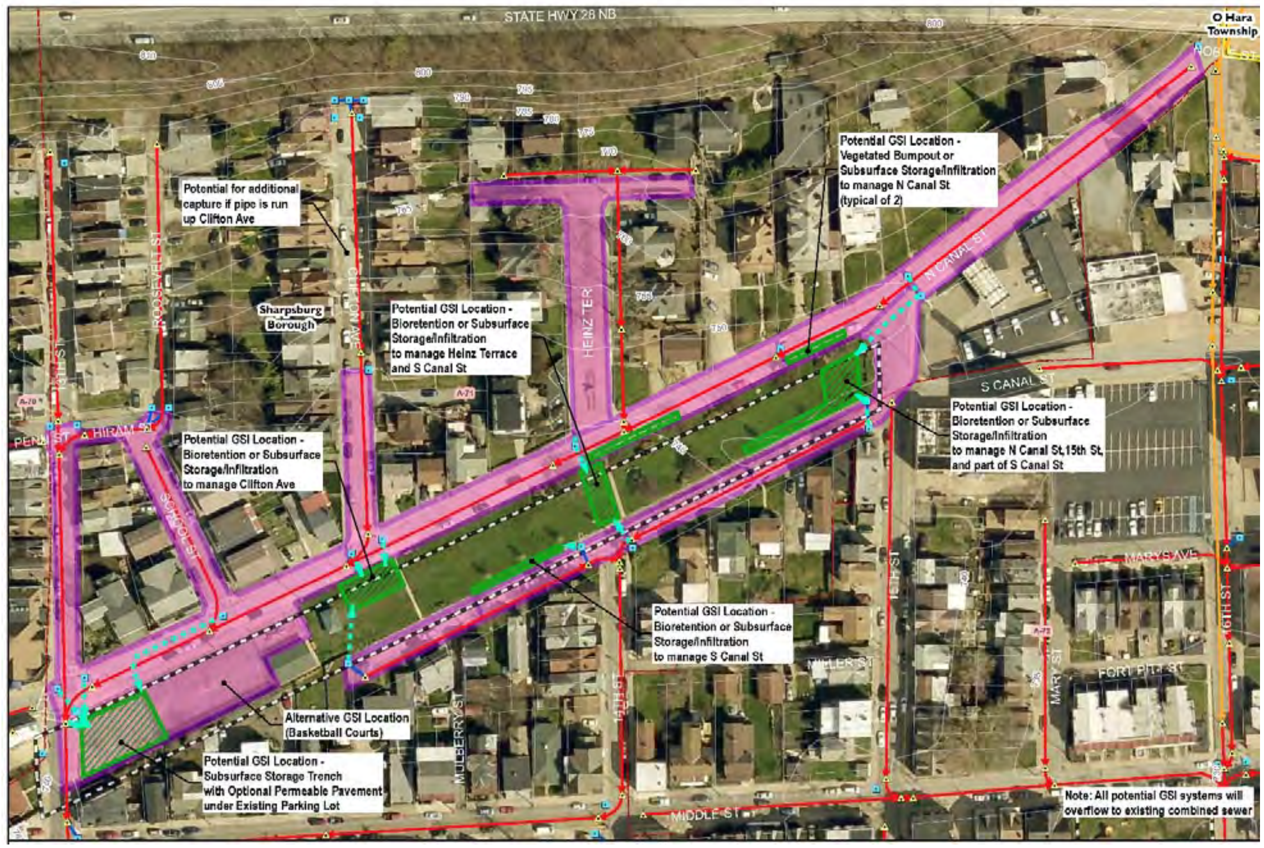
- Constraint
- Opportunity

Constraints:

1. Existing gate entrance into playground for maintenance access.
2. Pipe crossing at Ann St may be impacted by existing telephone (9"x18", 3'9" dp), gas (6, 3'-1" dp and a 3'-6" cover), sewer (2'x3'.8'-1" dp) or water (6", 4' dp) lines.
3. This existing tree would need to be removed in order to install a Green inlet at this location.

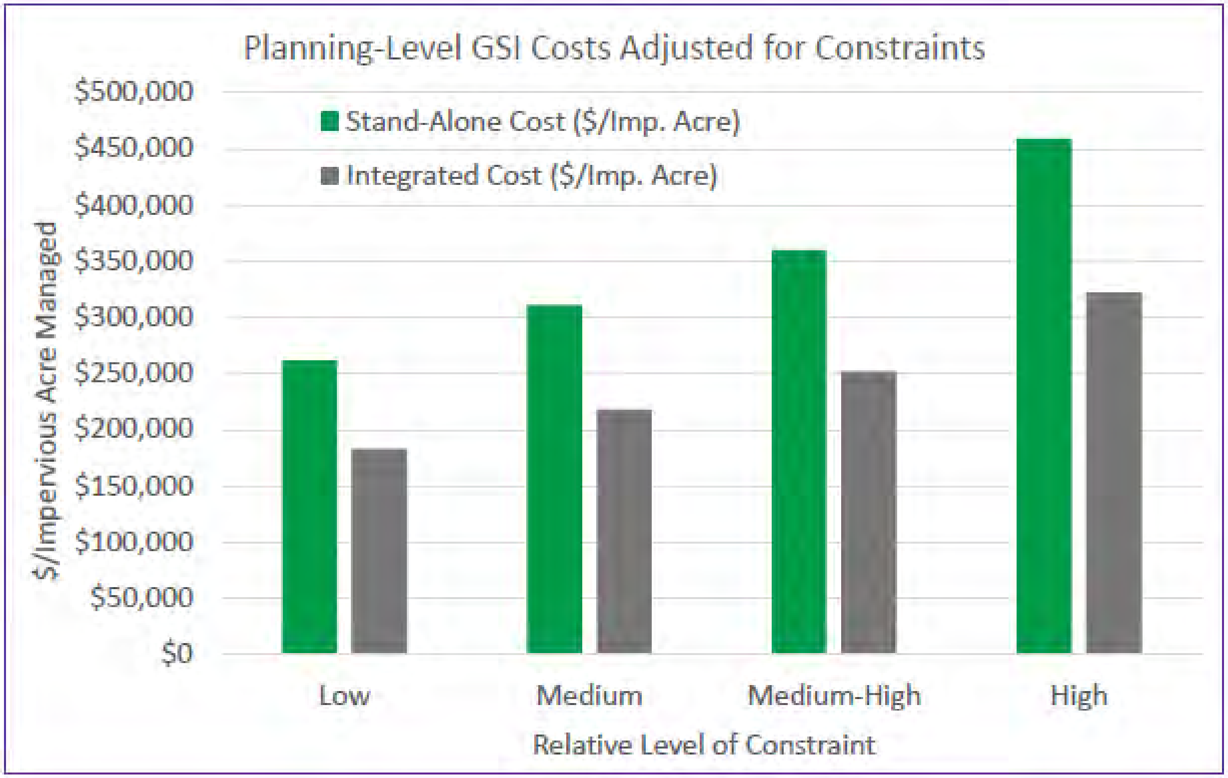
Identify Opportunities & Prioritize (aligns with project goals)

- High Runoff Capture (Stormwater Benefit)
- High Water Quality Benefit
- Less Conflicts
- Cost/Funding Availability
- Ownership (public vs. private)
- High Visibility (or low visibility)
- Planned Improvement Area
  - Repaving/ADA ramps
  - Park/School Upgrades
  - Other Public Improvements
- Partnership Potential

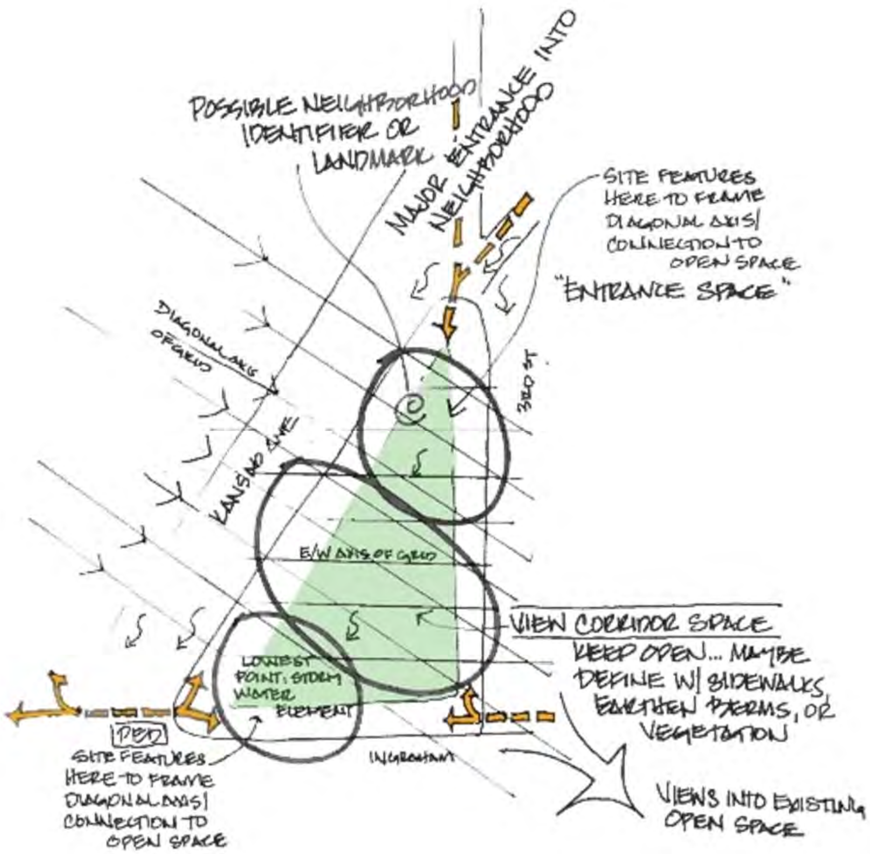


GI Planning Cost Considerations

- In general, from least to most expensive GI facilities: new development, redevelopment (integrated), retrofit (stand-alone)



Concept Plans Consider Site Context and Materials



Strategies for Reducing GI Implementation Costs

- Organizing GI into repeatable programs helps clarify costs by project type/application, which is often more meaningful than technology
- Regional planning analysis, including modeling optimization, can reveal cost-effective GI opportunities
- Economy of scale and changing the market
- Integrating with existing public works projects (utility work, street repaving/reconstruction, street trees, traffic calming, etc.)
- Increasing GI storage volume can often be done cost effectively

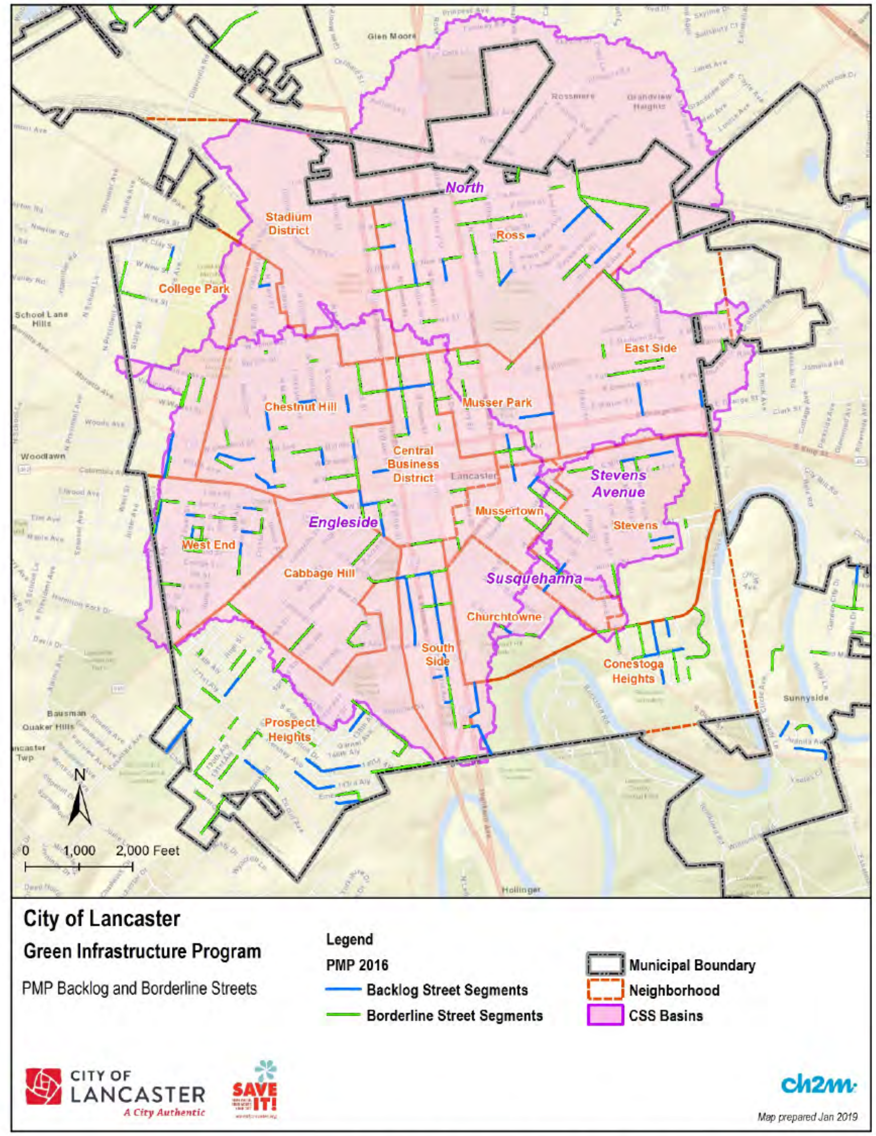


Figure 6.9 - PMP 2016 Backlog and Borderline Streets in the City (Data source: City)

Strategies for Reducing GI Implementation Costs

- Industry interest in public-private-partnerships (P3), credit trading, and at-risk retrofit delivery continues to drive business case evaluation
- Explore opportunities for large-scale O&M contracts (e.g., permeable pavements) – economy of scale
- Explore potential partnerships with local community groups, environmental organizations, etc – offset costs through low-cost or volunteer labor
- Implement! (the more projects that get implemented, the lower the costs will be over time)

Innovative GI Funding Strategies

- Stormwater Utilities to Fund O&M
  - Provide a stable revenue source
  - Equitable approach that bases fees on impact
  - Incentivize private investment through credit programs that reduce fees
- Alternative Financing Strategies
  - Public-private partnerships
    - Lancaster, PA example
- Fee in lieu / credit trading programs

Design

How can design yield green infrastructure projects that are practical, functional, cost-effective, and maintainable?

Overview of Design considerations that affect GI performance

- **Consider maintenance requirements and site conditions** when planning, selecting, and designing GI types
- **Design for minimal maintenance** where limited resources are available or when located on private property
  - GI types that require greater or specialized maintenance might be better suited for sites with rigorous ongoing maintenance, such as schools, commercial areas, urban plazas and public parks
- Be aware of **site constraints** that make GI installation difficult and avoid locating GI in these areas (e.g., slopes, dense utilities, high groundwater)
- **Design pre-treatment** that ensures long-term functionality
- **Design for ease of inspection and maintenance**, provide access
- **Select appropriate plants** for the application (e.g., salt & drought tolerant)
- **Design for adaptability** (e.g., backup drains, overflow structures, and underdrains)

Design Strategies to Overcome Typical Challenges

Poor soils – underdrains, micro-siphons, and innovative flow control structures

Shallow bedrock and/or highly constrained sites – high porosity storage media (arches, modular boxes, etc.)

Located in vulnerable locations along streets – reinforced curbs, delineators, reflectors, signage, pavement markings

Limited rooting volume – sand-based structural soil, suspended pavement systems / structural soil cells

Design Strategies to Overcome Typical Challenges

Prevent vandalism in urban sites – lockable grates/lids, permeable epoxy for landscape stone

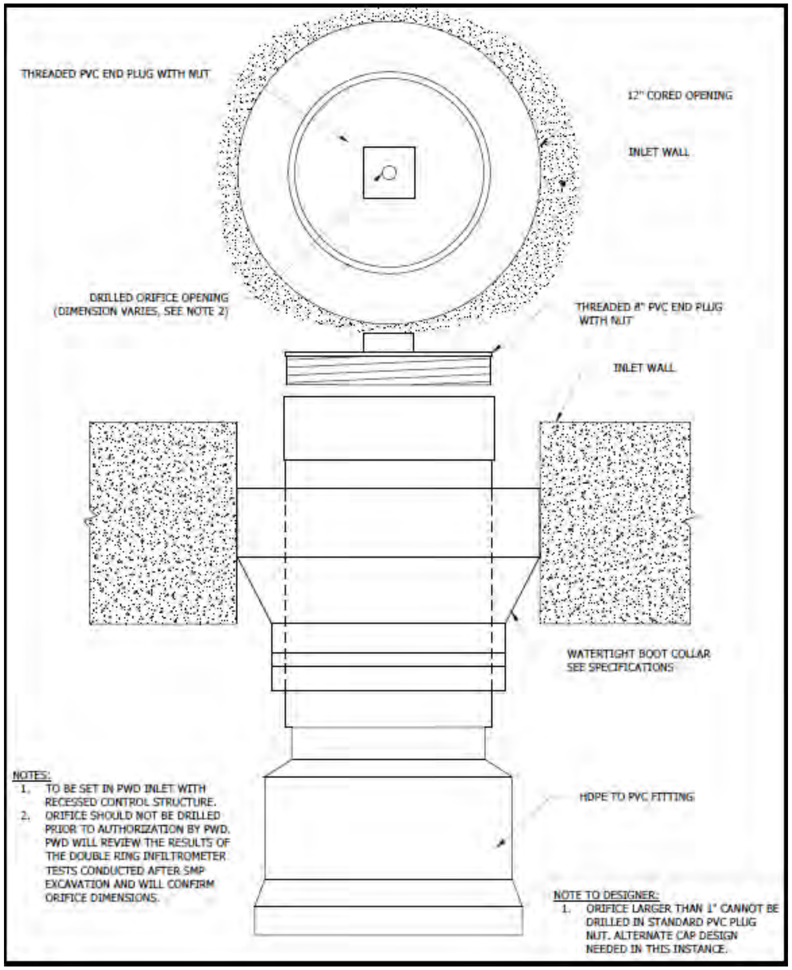
Located adjacent to structures / utilities – setbacks, impermeable liners, anti-seep collars

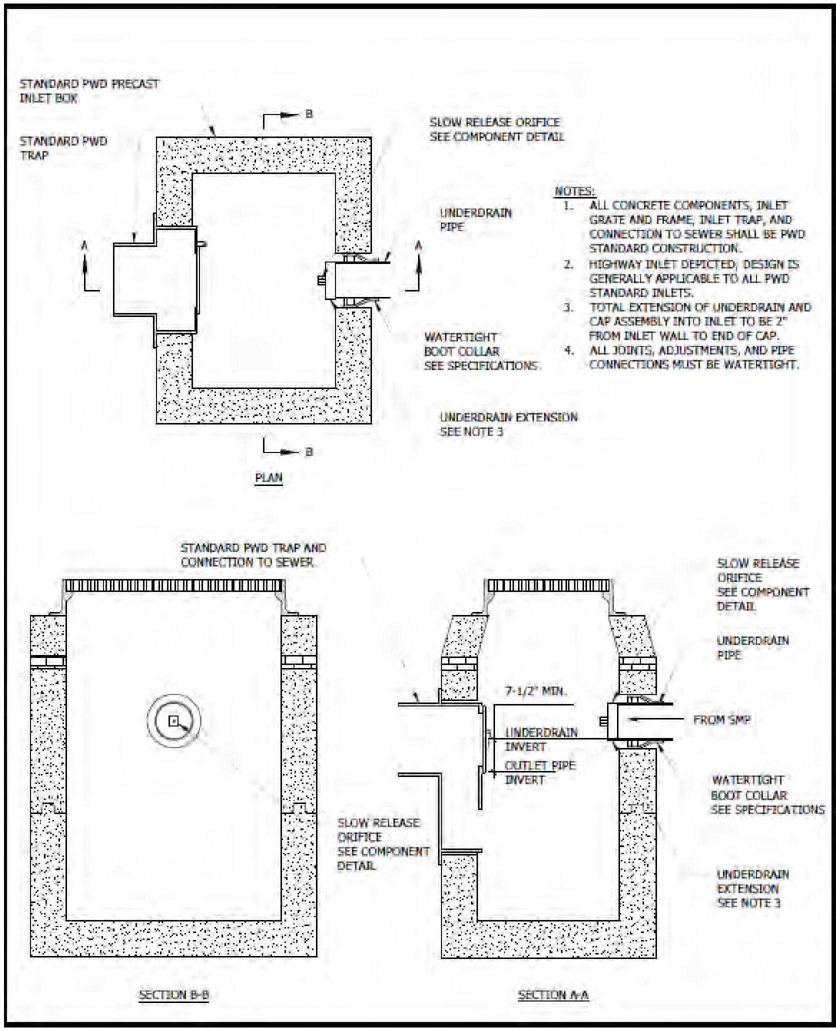
Large drainage areas w/ high sediment/trash loads – robust pretreatment in the form sediment forebays/energy dissipators or water quality inlets

Sloped Areas – step GI systems to maximize capture and reduce excavation

Solutions for Poor Soils

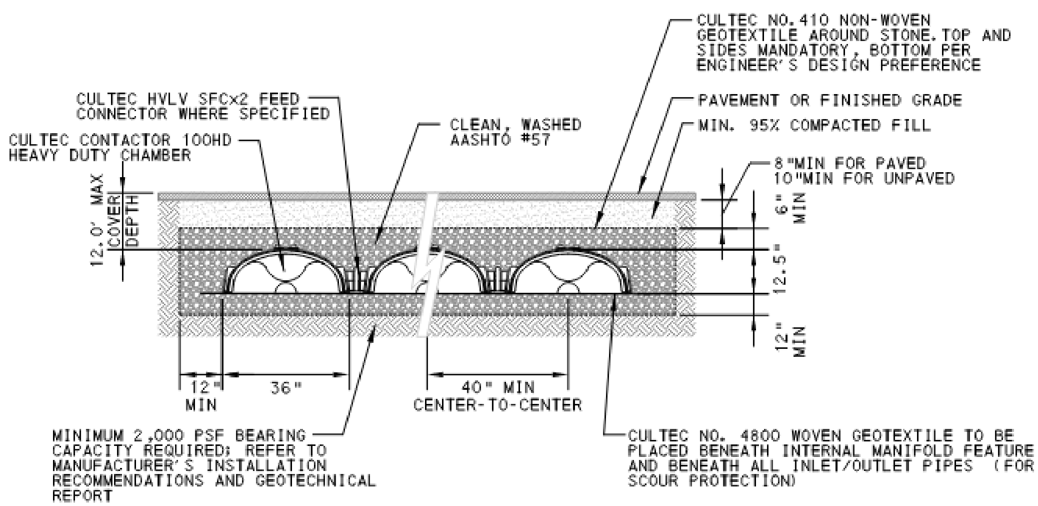
- Incorporate underdrain for slow release
- Orifice cap is adaptable

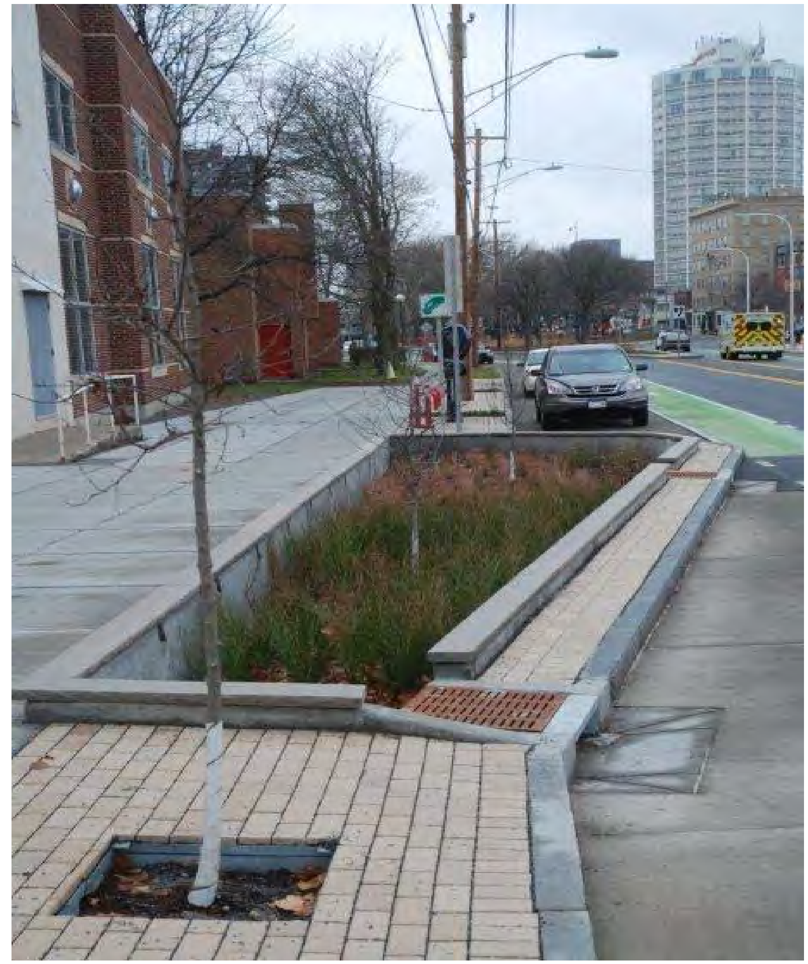




Solutions for High Bedrock or other subsurface constraints

- Shallow Bedrock
  - Maintain separation (min 2')
  - Incorporate shallow surface GI (e.g planters)
  - Utilize high-capacity storage media (chambers, tanks)





High Capacity Storage Media

Recommended Setbacks

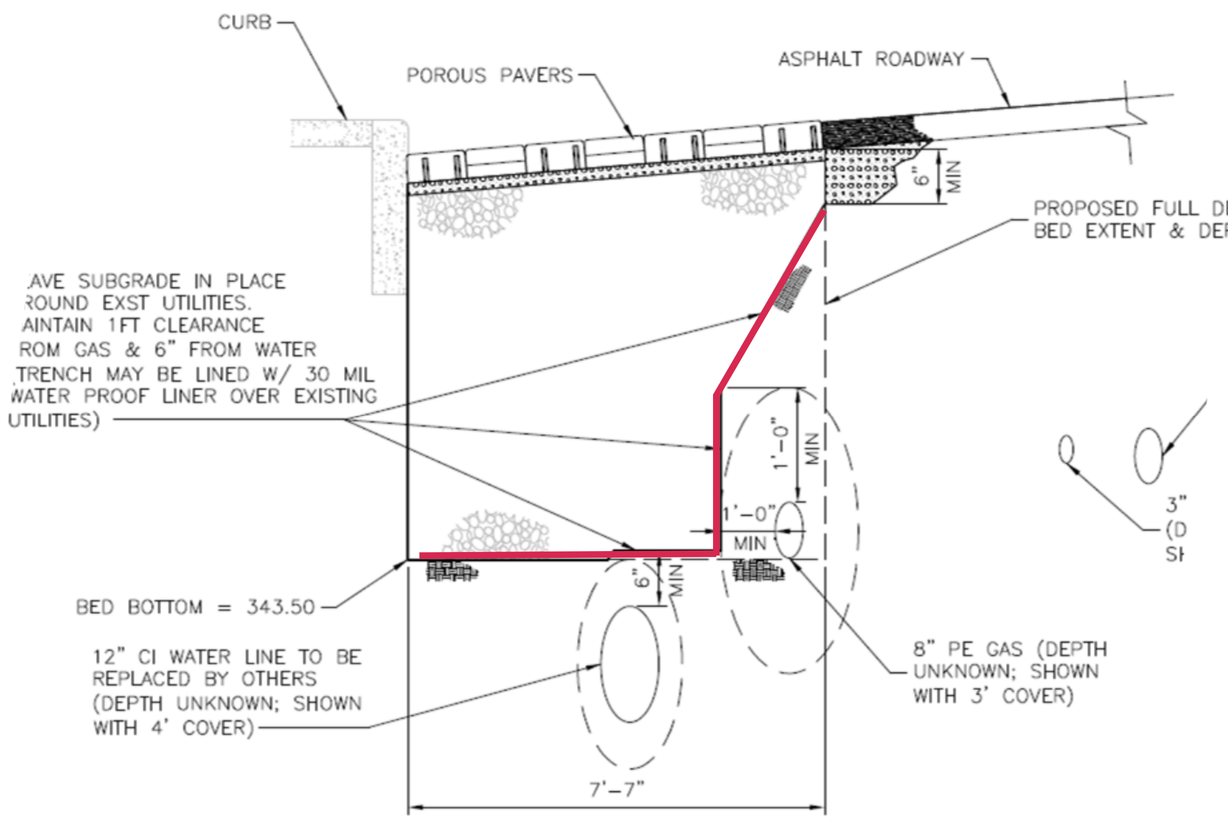
Constraining Feature[1]	Minimum Distance between GSI and Constraining Feature (ft)	Distance Type (Horizontal or Vertical)	Notes
Wetlands	10	Horizontal	N/A
Streams	20	Horizontal	N/A
Railroad	15	Horizontal	N/A
Building Foundation / Underground Structures (basements, tunnels, storage tanks, etc.)	10	Horizontal	Note if building has basement.
Utility Lines	3	Horizontal	N/A
Utility Lines	1 - 1.5	Vertical	Depends on utility size, type, age and condition.
Sewer Lines or Sewer Laterals	3	Horizontal	Infiltrating GSI should be prevented from infiltrating within a 1:1 slope from the invert of the sewer (i.e. zone of influence)
Utility Infrastructure (underground vaults, manholes, traffic lights, telephone poles, 'No Parking' signs, parking meters, guy wires etc.)	5	Horizontal	N/A
Fire Hydrant	3.5	Horizontal	N/A

Constraining Feature[1]	Minimum Distance between GSI and Constraining Feature (ft)	Distance Type (Horizontal or Vertical)	Notes
Trees / Vegetation	10 ft radius from tree center	Horizontal	Depends on condition of tree, relative benefits of new GSI vs. existing tree preservation. If necessary, use shovel or soft-excavation and avoid tree roots.
ROW Property Lines	3	Horizontal	To protect systems from future construction on adjacent parcels.
Non-ROW Property Lines	5	Horizontal	5 ft minimum. 10 ft preferred.
Infiltration-Limiting Layer (bedrock, high groundwater, etc.)	2	Vertical	Up to 3 ft.
Other Infiltration Facilities (other GSI practices, drain/disposal fields, seepage pits, etc.)	50	Horizontal	N/A
Steep Slopes / Landslide Prone Areas	50 - 200	Horizontal	200 ft from down-gradient slopes greater than 20%. Geotech analysis required if facility affects slope greater than 15%. Moderate to steep slopes (5% - 25%) should be considered a constraint to GSI placement.
Curbs, Curb Ramps, Sidewalks to Remain	2	Horizontal	N/A
Inlets to Remain	2	Horizontal	N/A
Crosswalk	5	Horizontal	Planters/curb extensions may be within or closer than 5 ft. from crosswalks

[1]Practitioners should use engineering judgment for setbacks to constraints not included such as subway entrances, driveways, fences, bus stops etc.

Solutions for Utility & Structure Conflicts

- Maintain setbacks (typ. 3'-5')
- Use liners to prevent flow to structures/foundations
- Protect utilities with excavation offsets or use utility sleeve



GI System Loading Ratio Considerations

Table 4-3. Recommended Loading Ratios

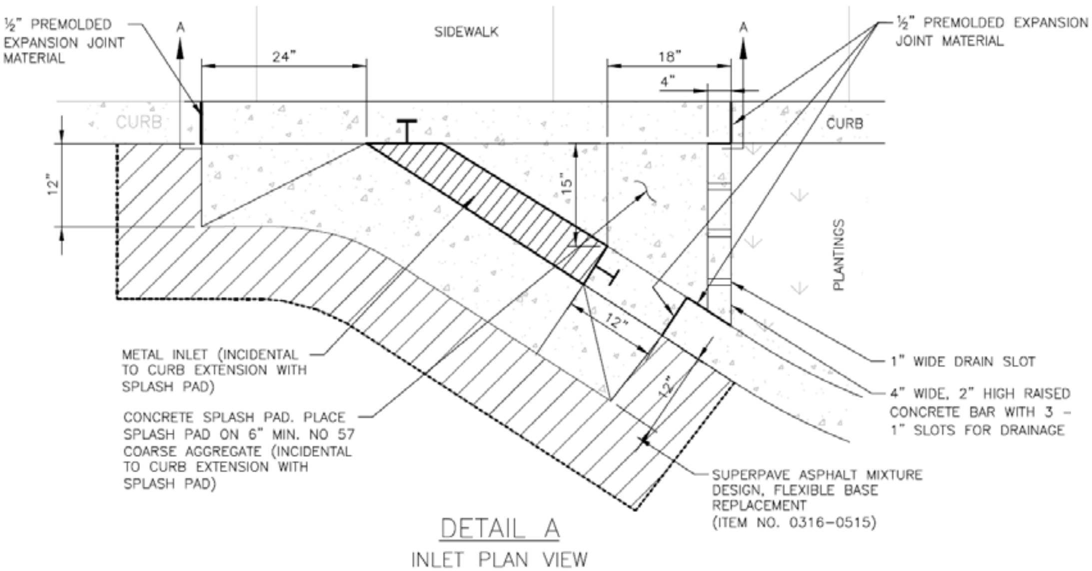
GSI Mechanism[1]	Surface Receiving Runoff	Recommended Loading Ratios of Impervious Drainage Area to GSI Area[2]
Infiltration / Runoff Reduction	Subsurface	5:1 - 12:1
	Surface (Vegetated)	10:1 - 20:1[3]
Slow Release	Subsurface	10:1 - 20:1
	Surface (Vegetated)	15:1 - 25:1[3]

[1]To protect against surface clogging, the loading ratio for permeable pavement should be kept at 3:1 or as recommended by manufacturers. However, the storage / infiltration system underneath permeable pavements can have higher loading ratios, provided the contributing drainage area is drained by inlets with pretreatment.

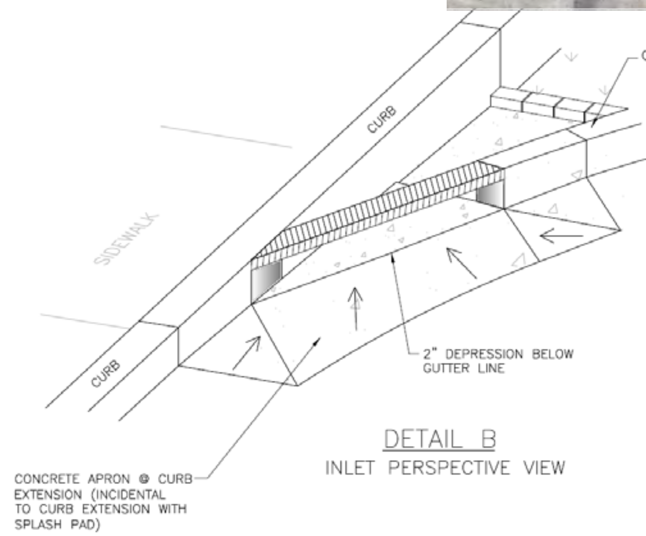
[2]Ratios are for stabilized drainage areas. Practitioners should consider the amount of sediment loading expected, factoring in ground cover and land use. Practitioners should consult a geotechnical engineer for special cases (e.g. carbonate soils, karst geography, landslide-prone areas, fractures, faults, other geologic features). Higher loading ratios necessitate more robust pretreatment.

[3]Loading ratios for surface systems could be increased by using high flow media.

Pretreatment: Curb Cuts and Concrete Aprons along Curb



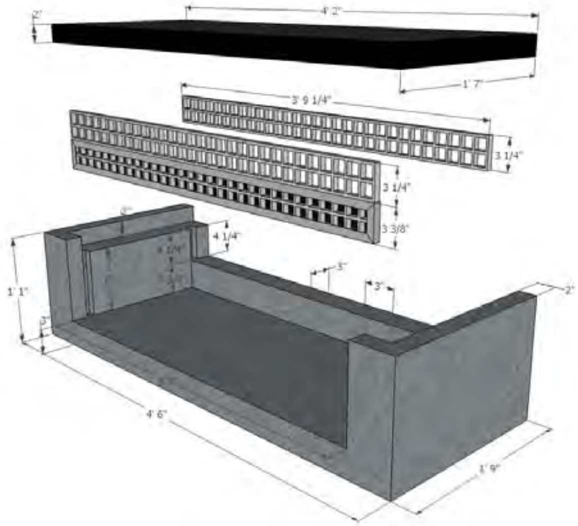
- Concrete aprons in gutter direct flow to surface GI and prevent bypass
- Wheel guards at curb cuts prevent vehicular damage
- Consider maintenance!



Surface GI Pretreatment Lessons Learned

- Cobble filled with sediment
- Surface soils clogged with sediment & debris

Integrated Inlet and Pretreatment Structures (Rain Guardian Turret and Bunker)

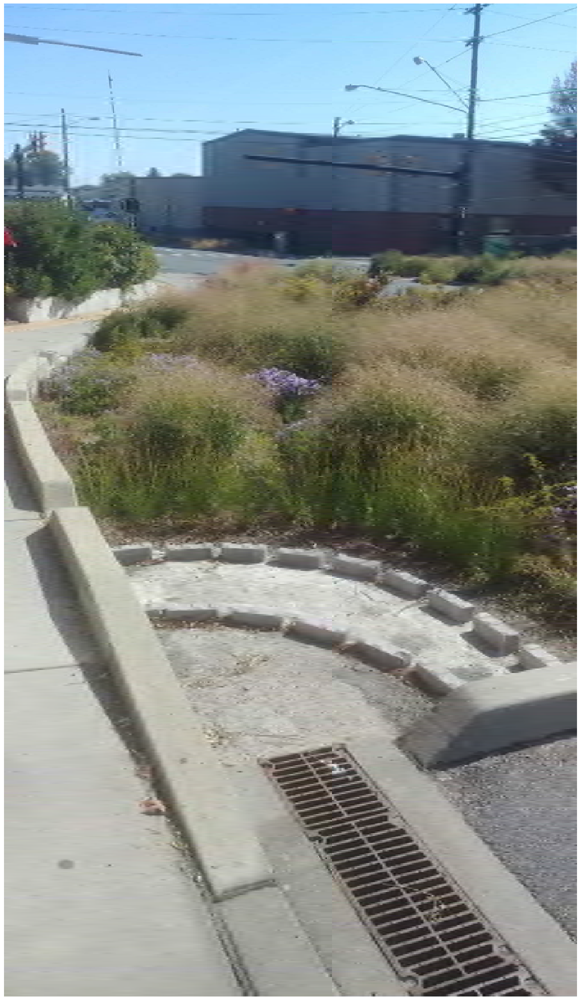


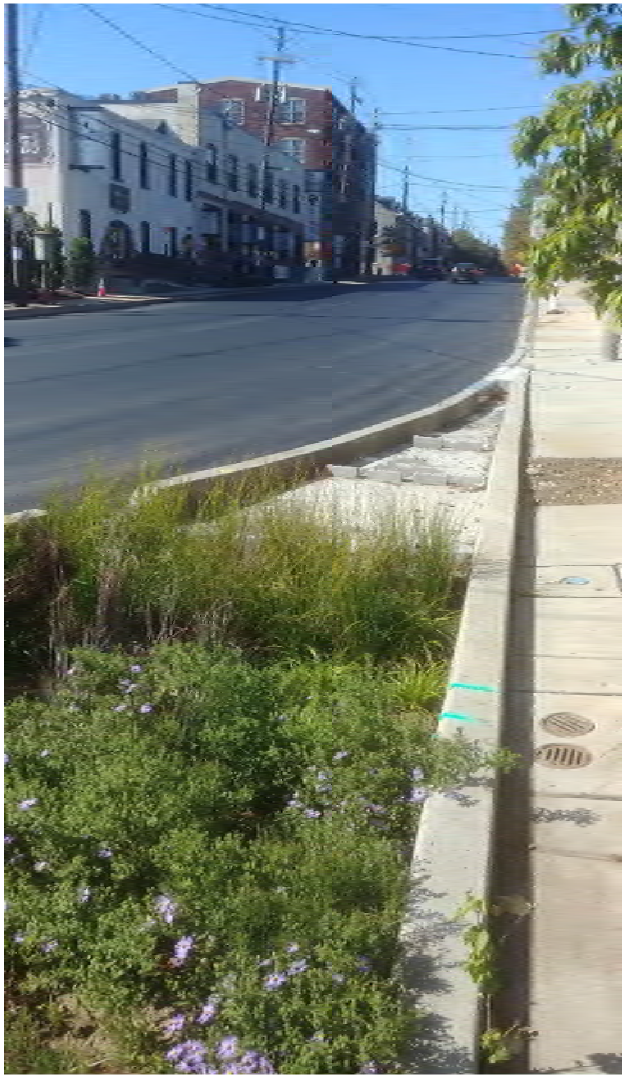
Forebay / Energy Dissipator

Stepped Forebay / Energy Dissipator

Pretreatment Structure w/ Sediment Sump

Retrofitted Forebay / Energy Dissipator

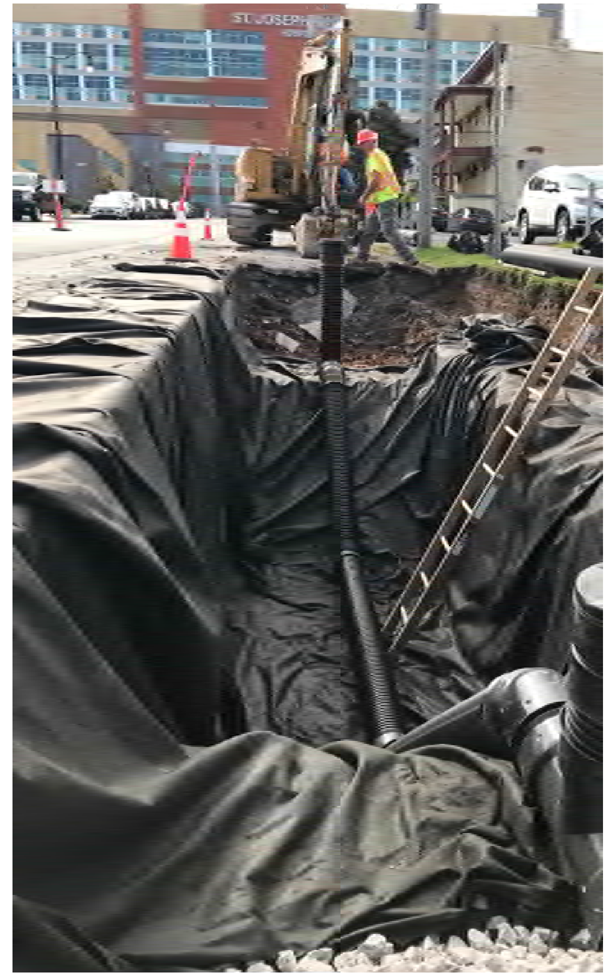


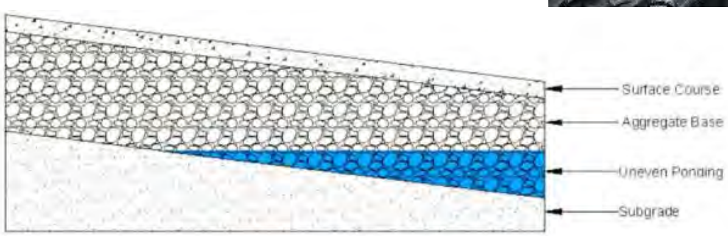


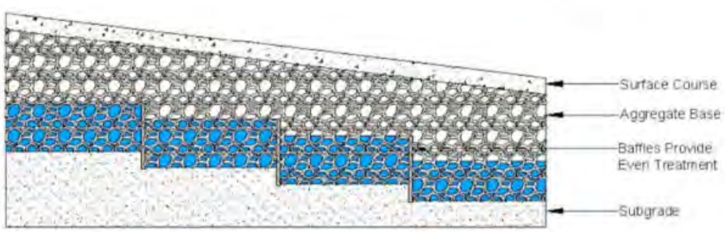
Steep Streets and ROWs

- How to manage runoff in steep areas?

Solution #1: Stepped Infiltration Trenches







Solution #2: Stepped Bioswales and Bumpouts

- Weirs and check dams help control flow and slopes

Simplified Grading makes it easier for Contractors

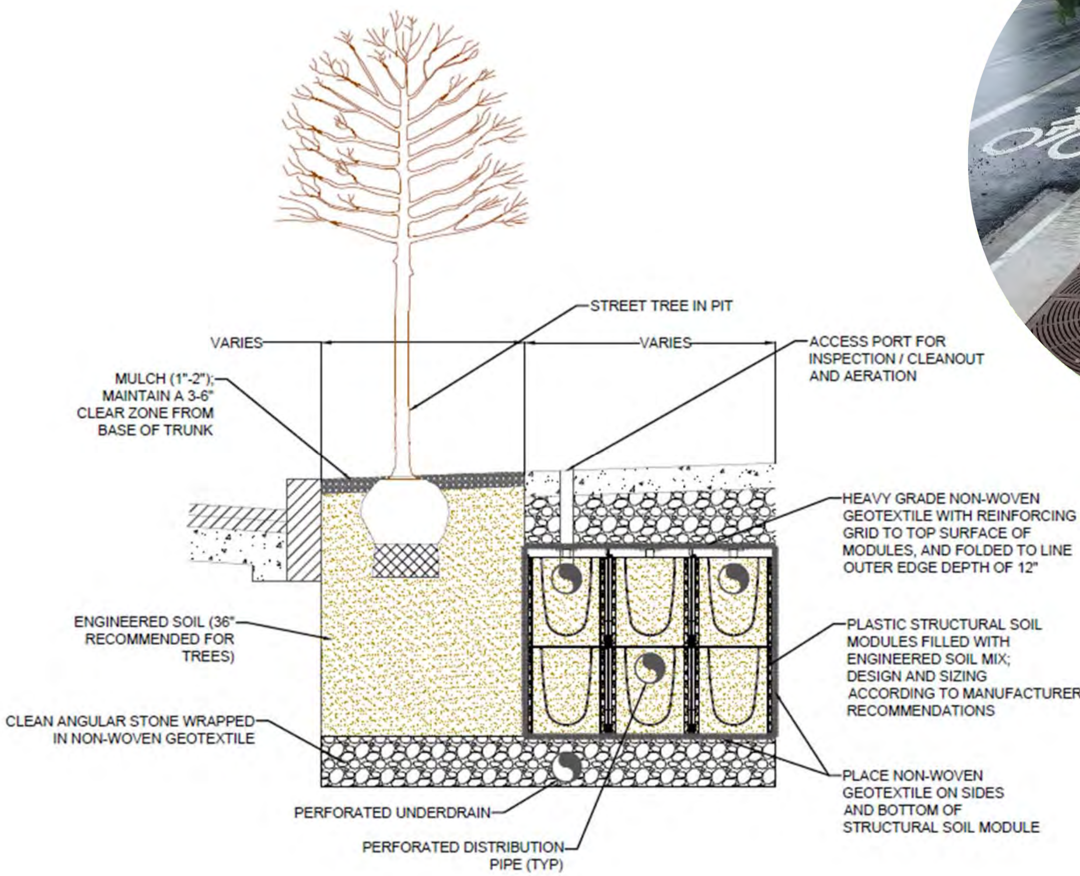
Achieving Ideal Soil Volumes for Enhanced Tree Pits / Trenches

Sand-Based Structural Soil

Root Channel

- Where trees are proposed in landscape strips/areas with **limited soil volume** potential, but have landscape areas with larger soil volumes on the other side of paved areas, consider the use of either **sand-based structural soil or piped root channels** that can direct tree roots to these larger soil volumes
- These 2 methods of bridging soil volumes will promote **healthier trees and protect sidewalks** from root upheaval

Typical Enhanced Tree Pit / Trench Detail



Vegetation Considerations During the Design Phase

- Accurately understand proposed soil and hydrologic conditions
- Employ strategies to avoid "bare areas"
- Consider a layered/mixed plant community approach rather than large swaths
- Realistically assess maintenance capabilities and community preferences

Accurately Understand Proposed Soil and Hydrologic Conditions

Accurately Understand Proposed Soil and Hydrologic Conditions

- Sand based soils = need primarily drought tolerant plants
- Roadway systems = need hardy, salt tolerant plants that can withstand stress
- Many "ruderal species" are well suited for roadway systems with sand-based soils (and no supplemental irrigation)
  - Ruderal species = a plant species that is first to colonize disturbed lands
  - Look to roadside meadow environments for examples of what might do well, not ornamental garden beds

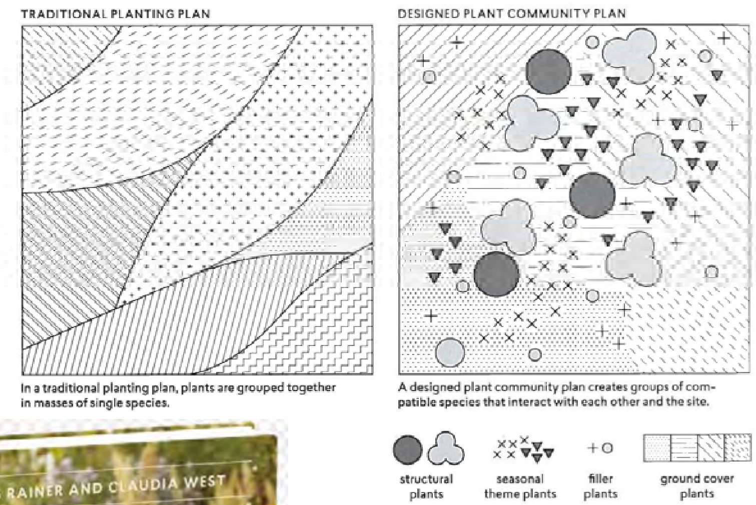
Employ Strategies to Avoid Bare Areas

Employ Strategies to Avoid "Bare Areas"

- Erosion control fabric/energy dissipators
  - Biodegradable erosion control fabric on slopes during plant establishment
  - Place "tougher plants" near water entry points to act as vegetative energy dissipators (in addition to structural energy dissipators)
- Plant densely (use denser spacing) to eliminate opportunities for weeds to establish
- Consider a layered "plant community" approach
  - "Green mulch" approach using diminutive filler groundcover species

Consider a Layered/Mixed Plant Community Approach

- Alternative way to approach planting design
- Biodiversity benefits!
- Plants – especially the "dynamic filler groundcovers" migrate to niche microclimates within a system
- Improves system resilience and ability to withstand fluctuating water and light conditions and disease/pests



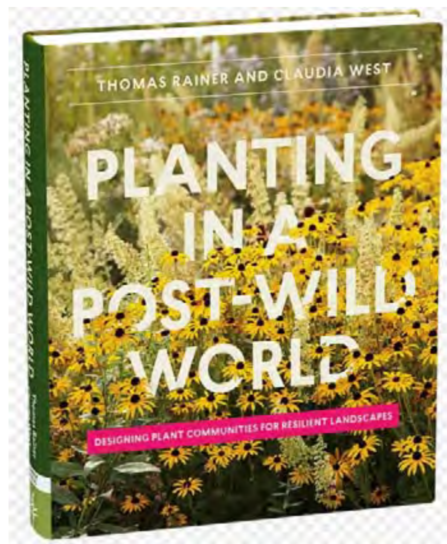


Diagram: Planting in a Post-Wild World by Thomas Rainer and Claudia West

Realistically assess maintenance capabilities and community preferences

- Keep plant palettes "simple" in terms of anticipated landscape maintenance tasks (grasses/perennials require similar types of maintenance vs. shrubs)
- Maintenance staff may have concerns about being able to distinguish weeds vs. desired plants
  - Provide images in any maintenance manuals
  - Again, anticipate this in the landscape design – goal is to avoid having bare areas that provide opportunities for weeds to establish
- Consider community preferences: more "naturalistic" palettes may look weedy to some audiences vs "garden-like" palettes

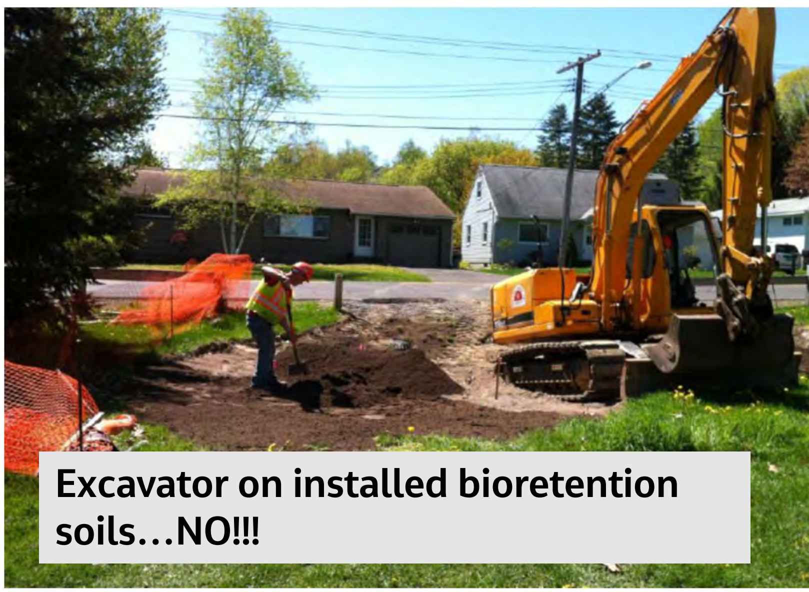
VS.

Construction

What construction practices work best for successful green infrastructure and what should be avoided?

Challenges with Contractor Familiarity with GSI – Onondaga County, NY

- Individually bid out projects, bundle projects where it makes sense location-wise and GI technology-wise
- Required management of several contractors unfamiliar with GI at the same time
- Significant administrative costs



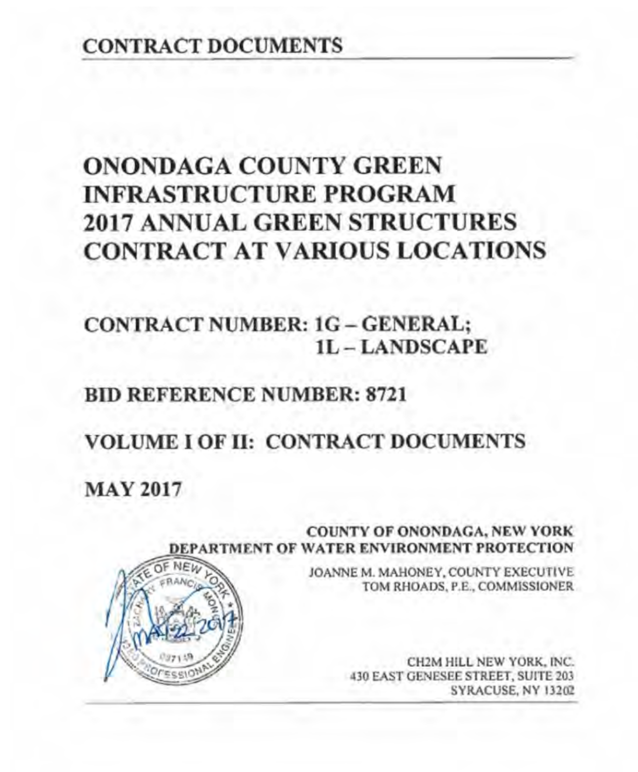
Excavator on installed bioretention soils…NO!!!

Compacting subsurface soils…NO!!!

Contractor Unfamiliarity – Protect What you Build!

Contractor Familiarity with GSI – How Onondaga County Addressed

- 2013
  - Development of the Green Infrastructure Term Construction Contracts (available at savetherain.us)
    - Standard set of details and specs
    - 120 standard specs, 90 standard details
    - General and Landscaping contractors
    - Unit price-based
- 2017
  - Contracts refined and rebid, further standardizing project delivery
  - Other municipalities in County utilize for GSI construction



CONTRACT DOCUMENTS

ONONDAGA COUNTY GREEN
INFRASTRUCTURE PROGRAM
2017 ANNUAL GREEN STRUCTURES
CONTRACT AT VARIOUS LOCATIONS

CONTRACT NUMBER: 1G – GENERAL;
1L – LANDSCAPE

BID REFERENCE NUMBER: 8721

VOLUME I OF II: CONTRACT DOCUMENTS

MAY 2017

COUNTY OF ONONDAGA, NEW YORK
DEPARTMENT OF WATER ENVIRONMENT PROTECTION
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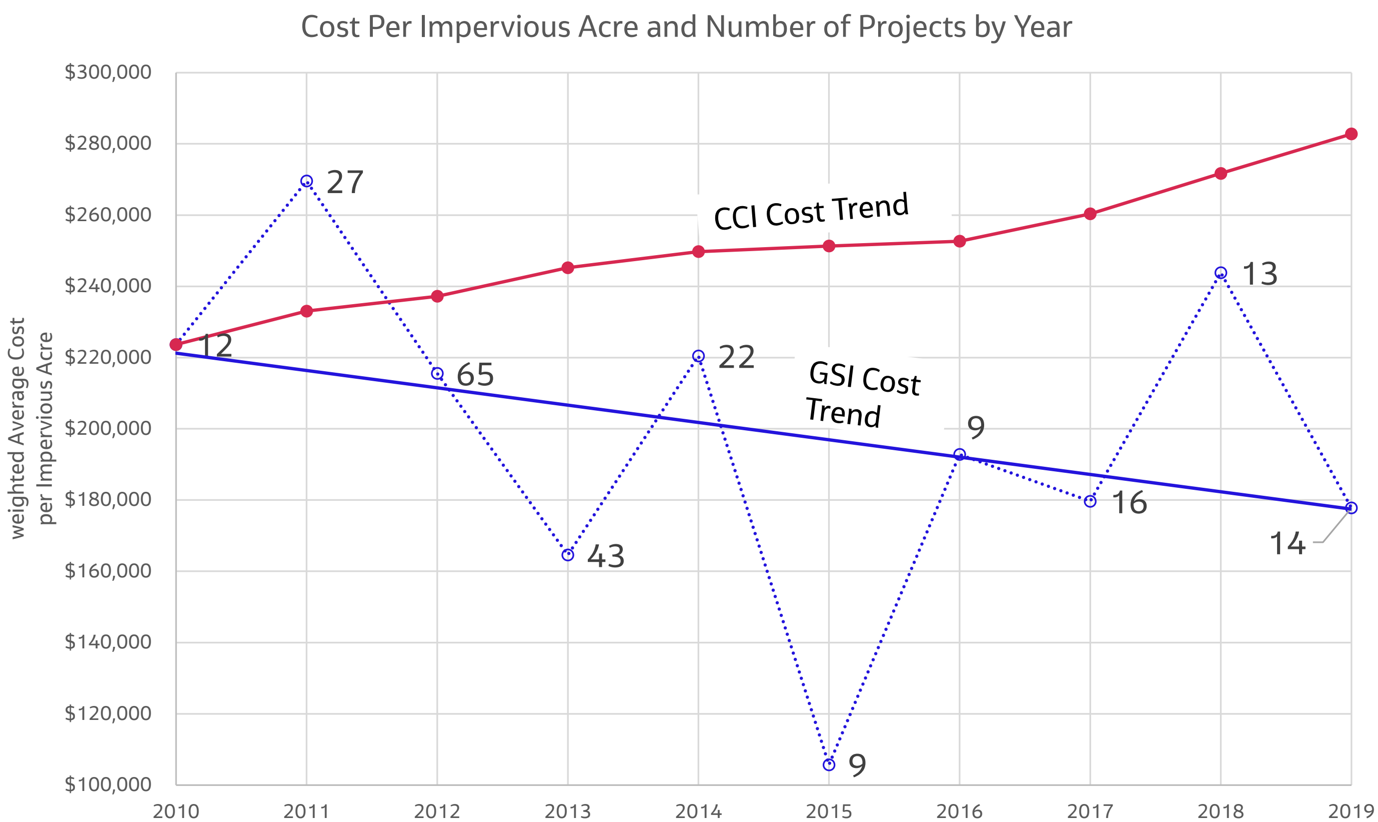
Combined with implementing standard details and constructability reviews, GSI costs trended downward



Typical Construction Sequence Flow Chart

Sequencing and Staging

- Construct GI structures after all other construction activity
- Divert runoff around GI structures during construction
- E&S controls installed to protect subgrade, installed materials, and stockpiled materials until drainage area is stabilized
- Consistent construction access routes to minimize soil compaction
- Locate concrete wash-outs and sediment basin/traps outside of GI structure drainage areas

Erosion & Sedimentation Control

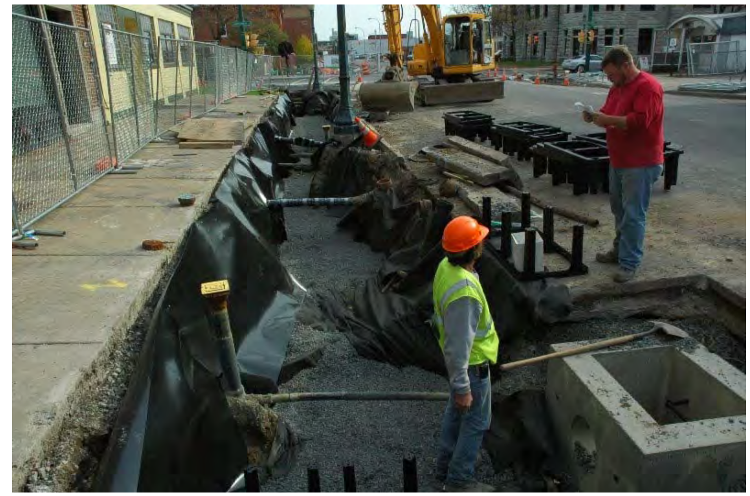
- Observe E&S control measures immediately before and after rain events
- Fencing & signage clearly identify sensitive areas
- Construction activities kept sufficiently away from sensitive areas
- Disturbances minimized to required area
- GI structures not collocated with temporary sediment basins or traps
- Temporary diversion channels and sand bags to route runoff around GI structures

Materials: Geotextiles, Liners, Storage Media

- Inspect for shallow limiting layers (groundwater table, bedrock, etc.)
- Inspect subgrade preparation for loose rocks prior to installing liners/geotextiles
- Liners, geotextiles, or sand layer placed immediately following subgrade approval
- Lap/seal seams of liners/geotextiles per manufacturer's instructions
- Geotextile secured at least 4 feet beyond excavated area
- Higher than normal precision needed for storage media final grades

Left side: correctly installed geotextile
Right side: incorrectly installed geotextile

Construction Lessons Learned: There Will Be Utilities, Known and Unknown!



Historic structures/features…

Working around Utilities

- GI and existing utilities can coexist; utilities must be protected according to plans and specs
- When a previously unidentified utility is encountered, the inspector should confirm the contractor halts work and notifies the specific utility company to discuss potential solutions

Pennsylvania811

Grading & Drainage

- Success of GI is directly related to site grading
- Inspect that components are installed at their design elevations and depths
- Final elevations for surface facilities must account for both surface treatments (mulch and cobbles) and anticipated settling of engineered soils
- Minimize any runoff bypass at inflow points
- Also inspect: catch basins, outlet control structures, check dams, weirs, outlets, and/or underdrain pipes as applicable

Planting

- Inspections of plant material is typically conducted by the landscape architect
- Document that all plant materials and trees have been reviewed and approved
- Plant size and conditions conform to plan schedule, drawings, and specifications
- All planting areas have been properly (but not overly) mulched
- Biodegradable erosion control fabric installed according to plans (usually on slopes)
- Plant material is installed in correct locations, spacing, and orientation

Construction Inspection Key Steps

- Pre-construction meeting AND pre-planting meeting
- Review construction material cleanliness and conformance
- Multiple inspections at critical stages
- Final inspection and site walk-through
- On-going inspections during plant establishment and warranty period

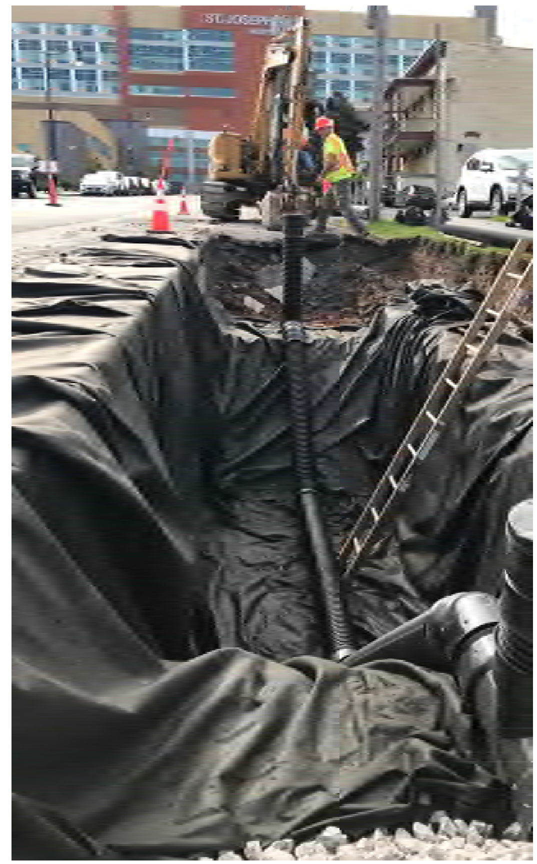
Key Construction Recommendations for GI Projects

- Conduct frequent coordination meetings with contractor
- Educate contractor on the purpose of GI (designed for runoff retention / infiltration, compact only as necessary, etc.)
- When excavating in ultra-urban areas, expect the unexpected, such as utilities (active and abandoned), train tracks, old structures, etc.
- Be prepared for the challenge of making quick field decisions while staying true to the original design goals
- Make sure materials are as specified (sand-based structural soil, clean washed aggregate, etc.)

The Good, the Bad, and the Ugly

Have you seen similar successes and/or issues with green infrastructure construction in your community?

Good – uncompacted subsurface soils, proper geotextile overlap



Ugly – infiltration stone not properly washed – fines!

Good – proper installation of bioswale section

Good – creating a template for proper grading of bioswale

Bad – bioswale grading; where is the runoff supposed to go?

Ugly – liner/waterstop at building interface; needs to extend higher

Ugly – not protecting porous pavement surfaces!

Good – proper installation method of soils to protect surrounding areas

Maintenance

Why is it important for green infrastructure and how can it be improved?

Why is it critical?

- Ensure long term performance of *Green Infrastructure*
- Protect capital investments
- Important for aesthetics (landscaping trees)
- Meet regulatory requirements, public and private
- Public health issues
- Long-term investment that needs maintenance just like anything else!

Common Failures / "Lessons Learned"

- Signage and education are critical to long term success of GI features
- "What are those weeds doing in that planter?"
- "Trash collects where water collects"
- "Relax, there's a filter in that inlet"
- "Will I get ticketed if I park in this bioswale?"

Barriers to Effective Maintenance

- Consistent inspection and clear maintenance procedures
- Lack of specialized equipment
- How to integrate new and different O&M protocols into existing O&M programs and operating budgets?

Maintenance Inspections

1. Bio-retention Area

____Ponding present? (Should drain entirely within 48 hours)
____Vegetation in healthy condition?
____Vegetation maintained properly?
____Vegetation replacement needed?
____Erosion present?
____Litter/trash present?
____Sediment deposits present?
____Adequate mulch / organic matter (3-4 inches thick)?

OVERALL RATING (circle one)

0 = No Deficiencies
2 = Routine Maintenance Required
1 = Monitor (potential for future problem exists)
3 = Immediate Repair Necessary

GI Maintenance Procedures

- **Many overlap with existing maintenance activities**
- Vary based on primary system function, visibility, BMP size, drainage area size, land cover/use, season, etc.
- High visibility GI systems typically require more maintenance
- Inspections required to meet regulatory requirements
  - 100% of GI practices in County inventory, every 5 years

Typical GI Maintenance Activities

- Removal of trash from site
- Removal of accumulated sediment and organic material (i.e. leaf litter)
- Control of invasive and non-target vegetative species
  - hand pulling to ensure removal of roots and/or treat with env. benign and non-soluble herbicide
- Control of target vegetation by pruning, mulching and reseeding
- Permeable pavement vacuuming
- Structural repairs, erosion control, and other corrective needs
- Avoid excessive compaction by mowers/vehicles

Winter Maintenance

Inspect Your GSI While It's Functioning, In the Rain!

Spring Maintenance Timing – Before Things Get out of Hand!

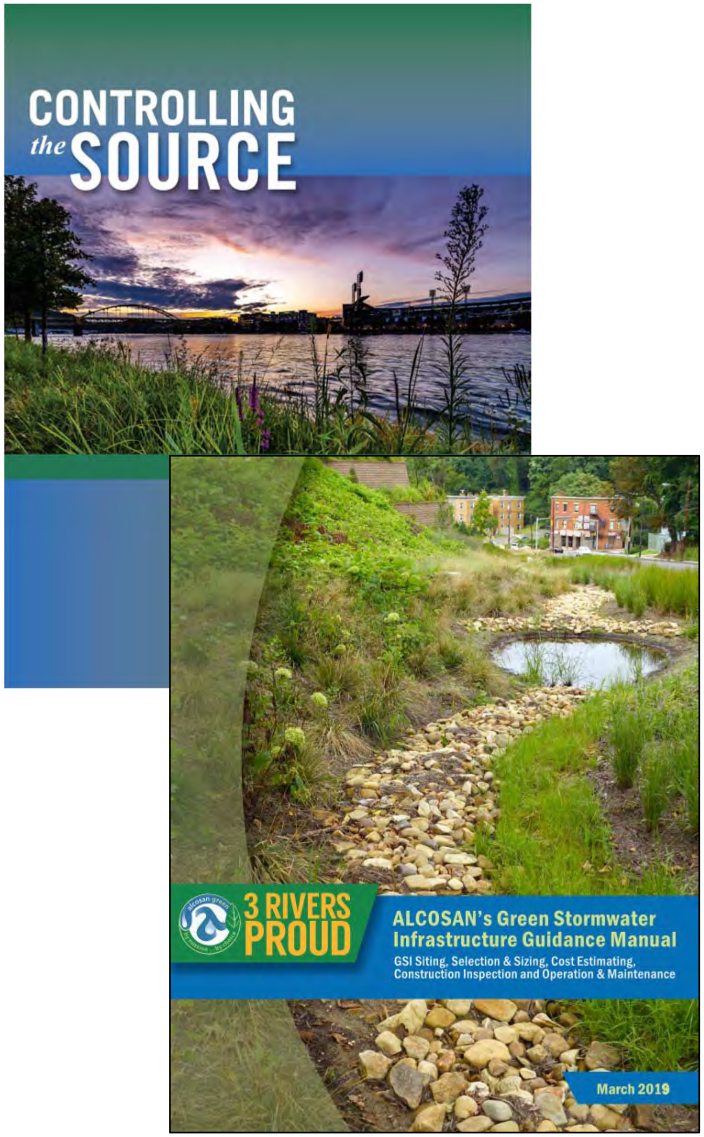
Same site, different year, no maintenance done until September!

How the Bioswale should look…

Resources

GI Maintenance Guidance Resources

Reference Name	Publishing Agency	Date Published/ Updated	Link
ALCOSAN's Green Stormwater Infrastructure Guidance Manual	ALCOSAN	2019	https://www.alcosan.org/docs/default-source/grow/alcosan_guidancedocs_march2019.pdf?sfvrsn=7c5d69ae_4
Addressing Green Infrastructure Design Challenges in the Pittsburgh Region Fact Sheet Series	EPA, EnvironmentalProtection Agency	January 2014	Addressing Green Infrastructure Design Challenges in the PittsburghRegion
Resource Guide for Planning, Designing and Implementing Green Infrastructure in Parks	National Recreation and Park Association	2017	Resource Guide for Planning, Designing and Implementing GreenInfrastructure in Parks
Green Solutions Fact Sheets	3 Rivers Wet Weather	2016	Green Solutions Bioswales Disconnected Downspout Green Roof Planter Box Permeable Pavement Rain Barrel Rain Garden Vegetated Filter Strip Vegetated Swale
Procedures Manual for Developers Chapter 9: Green Stormwater Infrastructure	Pittsburgh Water and Sewer Authority	January 2018	Procedures Manual for Developers
Pennsylvania Stormwater BMP Manual	Pennsylvania Department of Environmental Protection, Bureau ofWatershed Management	December 2006	Pennsylvania Stormwater BMPManual
Green Stormwater Infrastructure Planning & Design Manual	Philadelphia Water	April 2018	Green Stormwater Infrastructure Planning & Design Manual
Green Streets Design Manual	Philadelphia Water, Philadelphia Streets	2014	City of Philadelphia Green Streets Design Manual
Best Management Practice (BMP) Toolkit	Westmoreland Conservation District.	2015 - 2016	Westmoreland Conservation DistrictBMP Toolkit



GI Maintenance Guidance Resources

- Controlling the Source, ALCOSAN, 2020
  https://www.alcosan.org/our-plan/plan-documents/controlling-the-source
- Staying Green: Strategies to Improve Operations and Maintenance of Green Infrastructure in the Chesapeake Bay Watershed, American Rivers (2013):
  http://americanrivers.org/wp-content/uploads/2016/05/staying-green-strategies-improve-operations-and-maintenance.pdf
- National Green Infrastructure Certification Program (NGICP):
  http://ngicp.org/
- The Importance of Operation and Maintenance for the Long-Term Success of Green Infrastructure, US EPA (2013):
  http://water.epa.gov/grants_funding/cwsrf/upload/Green-Infrastructure-OM-Report.pdf
- Stormwater BMP Maintenance, Chesapeake Stormwater Network:
  http://chesapeakestormwater.net/training-library/design-adaptations/stormwater-bmp-maintenance/
- American Rivers and Green for All (2013). *Staying Green and Growing Jobs: Green Infrastructure Operations and Maintenance as Career Pathway Stepping Stones.*
  https://www.greenforall.org/staying_green_and_growing_jobs_green
- American Society of Civil Engineers (2017). *Cost of Maintaining Green Infrastructure.* Edited by Jane Clary and Holly Piza. American Society of Civil Engineers: Reston, Virginia.
  http://www.asce.org/templates/publications-book-detail.aspx?id=25533
- City of Edmonton (2016). *Low Impact Development Construction, Inspection & Maintenance Guide, Edition 1.* City of Edmonton: City of Edmonton, Alberta, Canada.
  https://www.edmonton.ca/city_government/environmental_stewardship/low-impact-development.aspx
- Onondaga County (2013). *Save the Rain Program Green Infrastructure Maintenance Manual & Training Materials.* Onondaga County, New York.
  http://savetherain.us/wp- content/uploads/2012/03/MaintenanceBinder_Rev-april2013.pdf
- Philadelphia Water Department (2016). *Green City, Clean Waters: Pilot Program Final Report;* Philadelphia Water Department: Philadelphia, Pennsylvania.
  http://phillywatersheds.org/doc/Year5_EAPBody_website.pdf
- Philadelphia Water Department (2016). *Green Stormwater Infrastructure Maintenance Manual, Version 2.0.* Philadelphia Water Department: Philadelphia, Pennsylvania.
  http://documents.philadelphiawater.org/gsi/GSI_Maintenance_Manual.pdf
- Seattle Public Utilities (2009). *Green Stormwater Operations and Maintenance Manual.* Seattle Public Utilities: Seattle, Washington.
  http://www.seattle.gov/util/cs/groups/public/@spu/@usm/documents/webcontent/spu02_020023.pdf
- United States Environmental Protection Agency Office of Water (2013). *The Importance of Operation and Maintenance for the Long-Term Success of Green Infrastructure: A Review of Green Infrastructure O&M Practices in ARRA Clean Water State Revolving Fund Projects.* United States Environmental Protection Agency: Washington, DC.
  https://www.epa.gov/sites/production/files/2015- 04/documents/green_infrastructure-om_report.pdf
- Water Environment Federation (2014). *Green Infrastructure Implementation;* Water Environment Federation: Alexandria, Virginia.
  https://www.e-wef.org/Default.aspx?TabID=251&productId=38340815

Thank You! Questions?

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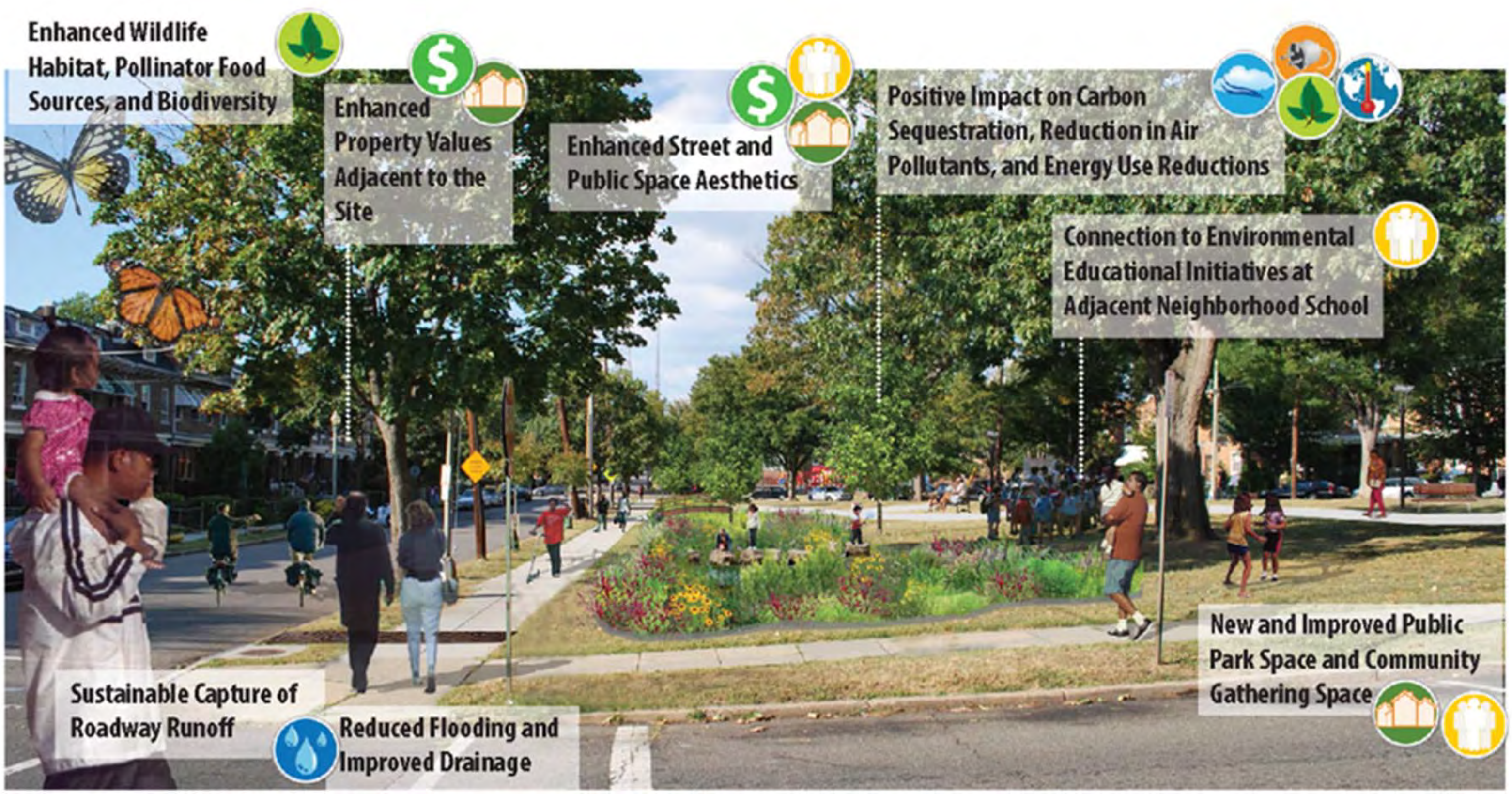
The Value Proposition for Green Infrastructure



	Project Type	Average County Construction Cost/Gallon of Runoff Captured or Eliminated
Green	Offset/Voluntary Projects with no County Contribution	$0.00
	City Road Reconstruction	$0.21
	GIF – Ground Based	$0.23
	Green Parks	$0.42
	Green Vacant Lots	$0.47
	Green Streets (Excluding Road Reconstruction Projects)	$0.58
	GIF – Green Roofs	$0.90
Gray	Gray Infrastructure – Storage	$1.41
	Gray Infrastructure – Sewer Separation	$3.78

Achieving Ideal Soil Volumes for Enhanced Tree Pits / Trenches

- Suspended pavement systems / structural soil cells are filled with engineered soil that creates enhanced rooting conditions while the modules themselves provide a structurally stable base for sidewalks

Clay soils, rainfall, space constraints, steep slopes Fact Sheet Series.pdf

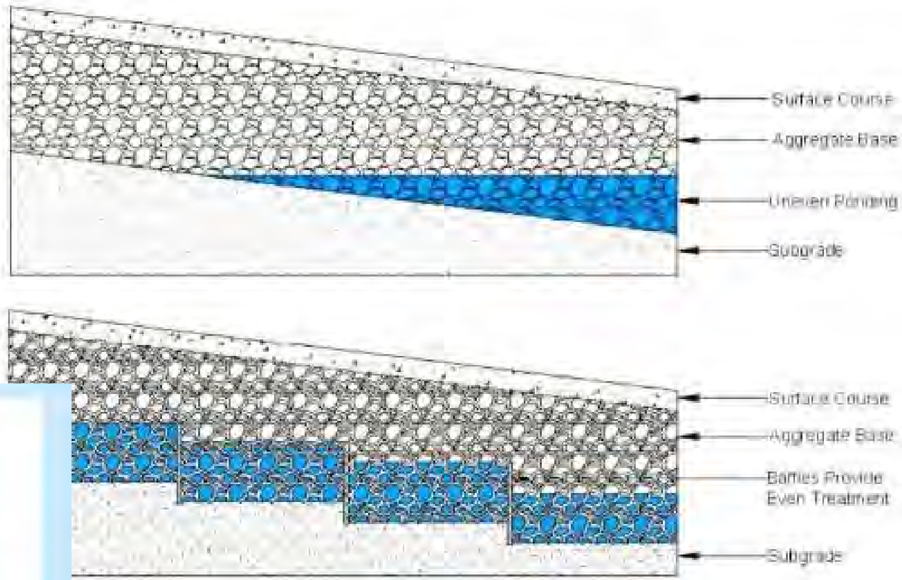
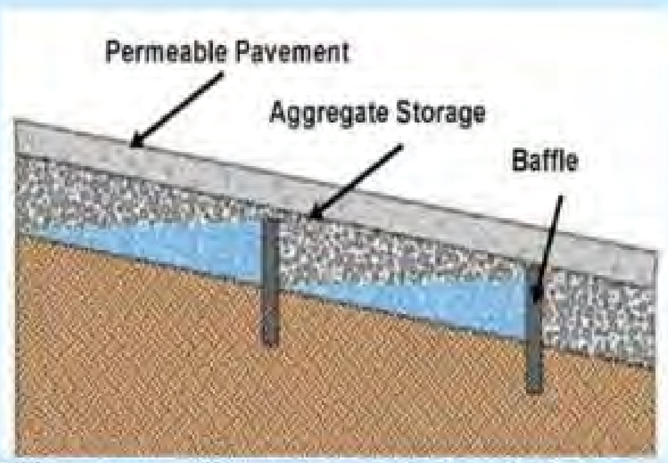


Figure 3-3. Baffles on Steep Slope
Baffles used in a sloping permeable pavement application increase the storage efficiency (Source: EPA Green Infrastructure Technical Assistance Program Addressing Green Infrastructure Design Challenges in the Pittsburgh Region: Steep Slopes, January 2014)



When permeable pavement is installed on a slope (max. 5% slope), baffles can be constructed beneath the pavement to increase water storage and promote infiltration.
Source: Adapted from http://perviouspavement.org/design/hydrologicaldesign.html